AN APPARATUS TO MAINTAIN A SURFACE FILM OF WATER FOR USE IN VEGETATIVE PROPAGATION

KARL A. GROSSENBACHER*

With three text-figures

VEGETATIVE propagation has long been of practical importance to nurserymen and others engaged in work with plants. The development of the theory of the hormone mechanism of root formation and availability of synthetic chemicals for treatment of cuttings has greatly increased the amount of work being done with vegetative propagation. Plant physiologists are interested in the phenomena of root formation as well as in the use of cuttings as a source of uniform experimental material. In the study of genetics of trees vegetative propagation becomes a valuable tool for the more accurate estimate of individual clones.

Doran (1) presents a summary of the work with trees and shrubs as well as an extensive bibliography. The standard practice has been to shade or cover propagating beds and to sprinkle the cuttings to prevent them from drying out during the period of root formation. Where leafless stems can be used, there is less evaporating surface and maintaining cuttings is a much simpler problem. For many species, however, it is necessary to use leafy cuttings, and their maintenance presents many problems. The water content must be kept up. They must have sufficient light to function properly and fungi must be controlled.

Raines (3) reports on a spray chamber technique for handling plant materials which promises to lead to new developments. Mitchell et al. (2) developed an out-of-door modification used to maintain cuttings in full sunlight. They found the most favorable environment for the propagation of slash pine (*Pinus caribaea* Morel.) to be "well drained sand . . . 75° – 90° F. . . . fine spray of water . . . on 5 minutes out of each 10-minute cycle for 10 to 12 hours each day." Others have pointed out that spray humidification in greenhouses has extended the limits of propagation of plants which are difficult to root (5).

Preliminary work in the greenhouses of the Harvard Biological Laboratories indicated that cuttings of several forest trees responded better in fuller exposure to sunlight than in the more conventional shaded beds. Tests were made with mechanical humidifiers as well as with intermittent spray. During the summer of 1944 an apparatus was developed and operated at the Harvard Forest. Taking advantage of full sunlight, out-of-

*This work has been financed by the Maria Moors Cabot Foundation for Botanical Research of Harvard University and was carried out at the Harvard Forest. The author wishes to thank C. T. Brown, Jr., S. H. Spurr, and P. R. Gast for their aid in the development and construction of this apparatus.

door propagating beds were equipped with a sprinkler system and an automatic control mechanism. This apparatus was designed to give maximum surface wetting with a minimum amount of water and was actually controlled by the evaporation of water from a surface film.

Cuttings of various forest trees were maintained in excellent condition. Satisfactory rooting was obtained with cuttings of red maple (*Acer rubrum*), sugar maple (*A. saccharum*), and paper birch (*Betula papyrifera*). No satisfactory rooting was obtained during the relatively short 6–8 week period with cuttings of hemlock (*Tsuga canadensis*), red pine (*Pinus resinosa*), white pine (*P. Strobus*), or white spruce (*Picea glauca*).

APPARATUS

Propagation beds, as illustrated in *Fig. 1,* were built with gravel drainage and heating coils, allowing a 6-inch depth of builders' sand for planting cuttings. Sprinkler pipes were placed 10 ft. apart (every two beds) with flat misting nozzles (#.031F, Spray Engineering Co., Somerville, Mass.) every 3 ft. They are oscillated by a motor-driven crank, connected by rods to lever arms clamped directly on the pipes. The oscillating pipes are connected by loops of garden hose. The water supply (40 lb. pressure) is controlled by a single solenoid valve. An emergency by-pass with a normally open solenoid valve has been installed to supply constant spray in the event of any power failures.

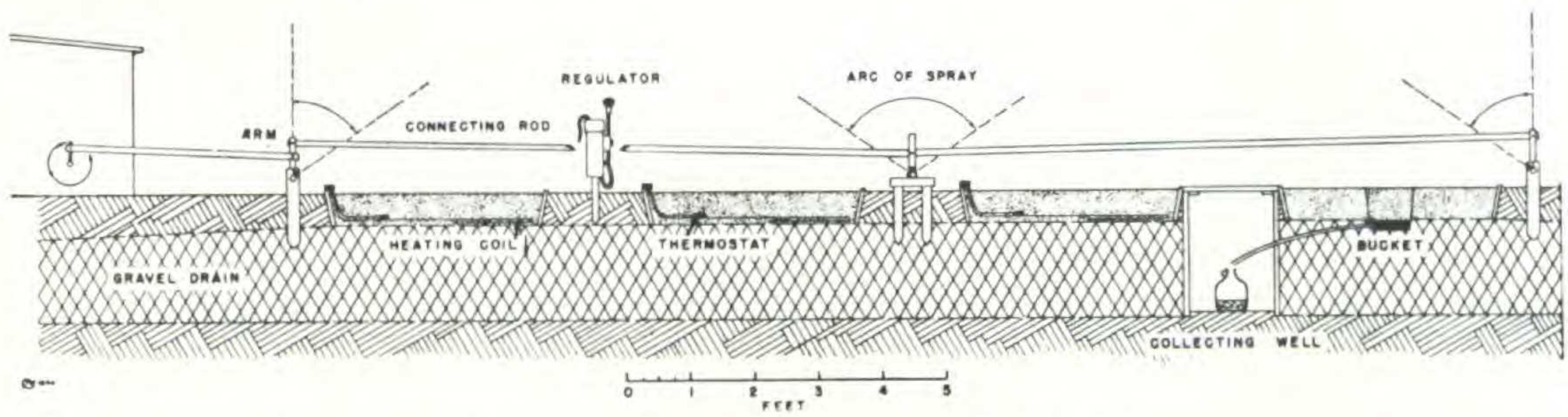

FIG. 1. Diagram of propagating beds.

The regulator, shown in *Fig. 2,* consists of a Livingston black bulb atmometer (B. E. Livingston, Riderwood, Md.) connected to a water-oil-mercury column. When a small amount of water is lost from the evaporating surface, the mercury moves up, making contact with the platinum wire activating the relay. This starts the oscillating motor and opens the solenoid valve. The regulator is so placed that water from the sprinklers falls on the evaporating surface, thereby replacing the water lost and opening the circuit. A distilled water reservoir is connected into the water column through a mercury safety valve to prevent undue water tension from developing in the regulator in case of mishap. By applying air pressure gently to the distilled water, the walls of the bulb can be conveniently flushed.

In order to reduce electrical action in the mercury-oil-platinum switch as

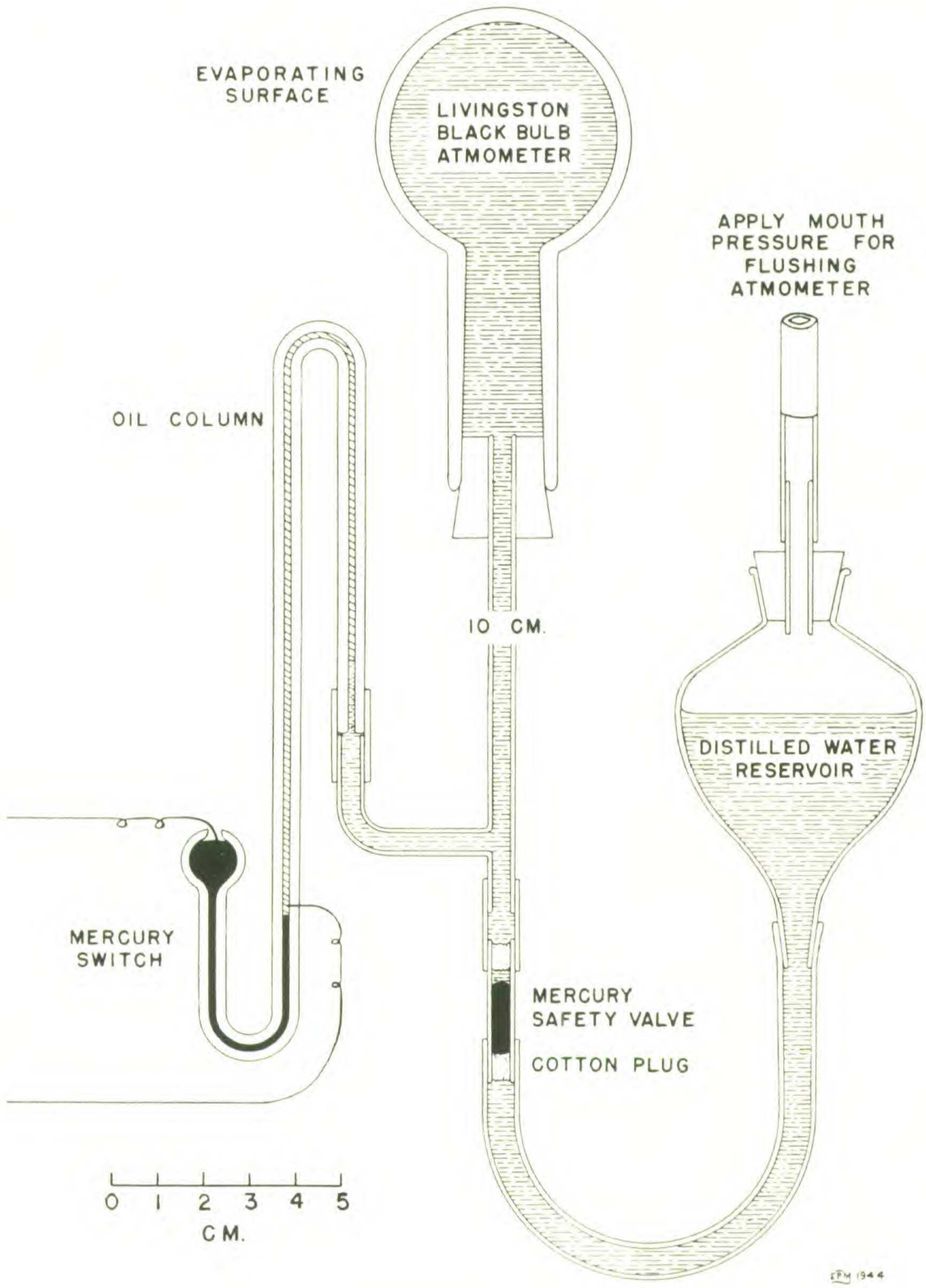

FIG. 2. Detail of regulator.

well as to assure uniformity of behavior, a two-coil, locking relay is used (Cenco #99740). The activator current is drawn directly from the 110-volt A.C. line with the load, relay coil, motor, and solenoid valve, in series. A single low amperage impulse (1/120 sec.) is enough to lock the relay in the on-position. A separate coil and circuit is used to open the relay, and the necessary impulse is drawn in a similar manner from the A.C. line. The circuit is closed by a contact point on a wooden idler wheel, which is driven by the crank shaft of the oscillating mechanism. While the idler wheel makes one revolution in 30 seconds, the crank shaft makes 5, thereby giving five sweeps of the sprinklers per 30-second period. The momentum of the apparatus is sufficient to carry the contact points past the make-position, opening the off-circuit and clearing the relay for the next starting impulse. A small amount of chattering occurs if water from the sprinkler has not opened the starter circuit during the 30-second on-period. With the regulator placed midway between pipes and well within the range of several nozzles, this can only happen occasionally in dry windy weather.

This regulator mechanism has two fundamentally weak aspects. The evaporating surface and porous walls of the atmometer tend to accumulate deposits of materials dissolved in the spray water. Also, the electric current causes sludge to form at the junction of the oil and mercury. Though satisfactory contact is made when relatively large amounts of sludge have accumulated, the sludge can be expected eventually to cause trouble. The present apparatus has been operated for more than three months without interruption.

PERFORMANCE

The oscillation of the sprinkler pipes can be adjusted to give satisfactory cover of the beds by changing the lever arms and connecting rods, etc. The two edge sprinkler pipes are set to supply a single bed with a short arc, thus giving a heavy watering to compensate for the effects of the wind. The center pipe swings through a larger arc, watering a bed on each side.

The regulator can be adjusted to give a wide range of performance. In order to maintain a film of surface water, the mercury in the outer arm of the mercury switch is put enough higher than the contact point nearly to balance the weight of water in the column supplying the bulb, thereby maintaining almost a free water surface on the bulb. Excess water drains off, and only a slight evaporation is necessary to start the sprinklers.

With this arrangement, the sprinklers turn on every 2 to 2½ minutes in bright dry weather, less frequently in cloudy weather, and only occasionally during the night. This means that the sprinklers are turned on about 240 times a day, or they run for about 2 hours out of the day, delivering 500 gallons over an area of about 500 sq. ft. (allowing for edge effects). This is equivalent to a rainfall of about 1.6 inches. However, a large portion of this water is actually lost by evaporation or blown away by the wind.

Records of sprinkler frequency were obtained with an independent circuit operating a chronograph. The drainage of water through the propagating bed was measured from three sampling buckets, as shown in *Fig. 1*.

Atmospheric temperature and humidity records were obtained in a standard weather shelter some 75 yards from the beds. Sample data for August 28, 1944, are presented in *Fig. 3*. The low temperature and high humidity of the preceding night kept the sprinkler off, and the drainage rate was therefore very low. As the day advanced, and the temperature rose and the humidity fell, the sprinkler came on more often, reaching by nine o'clock a fairly constant rate of 25 to 30 times per hour (highest recorded rate: 36 times per hour). The drainage for the 9 to 5 period reached the large amount of .326 cc per cm^2 per hour, being one of the highest drainage rates observed. As night came on and the humidity increased, the sprinkler

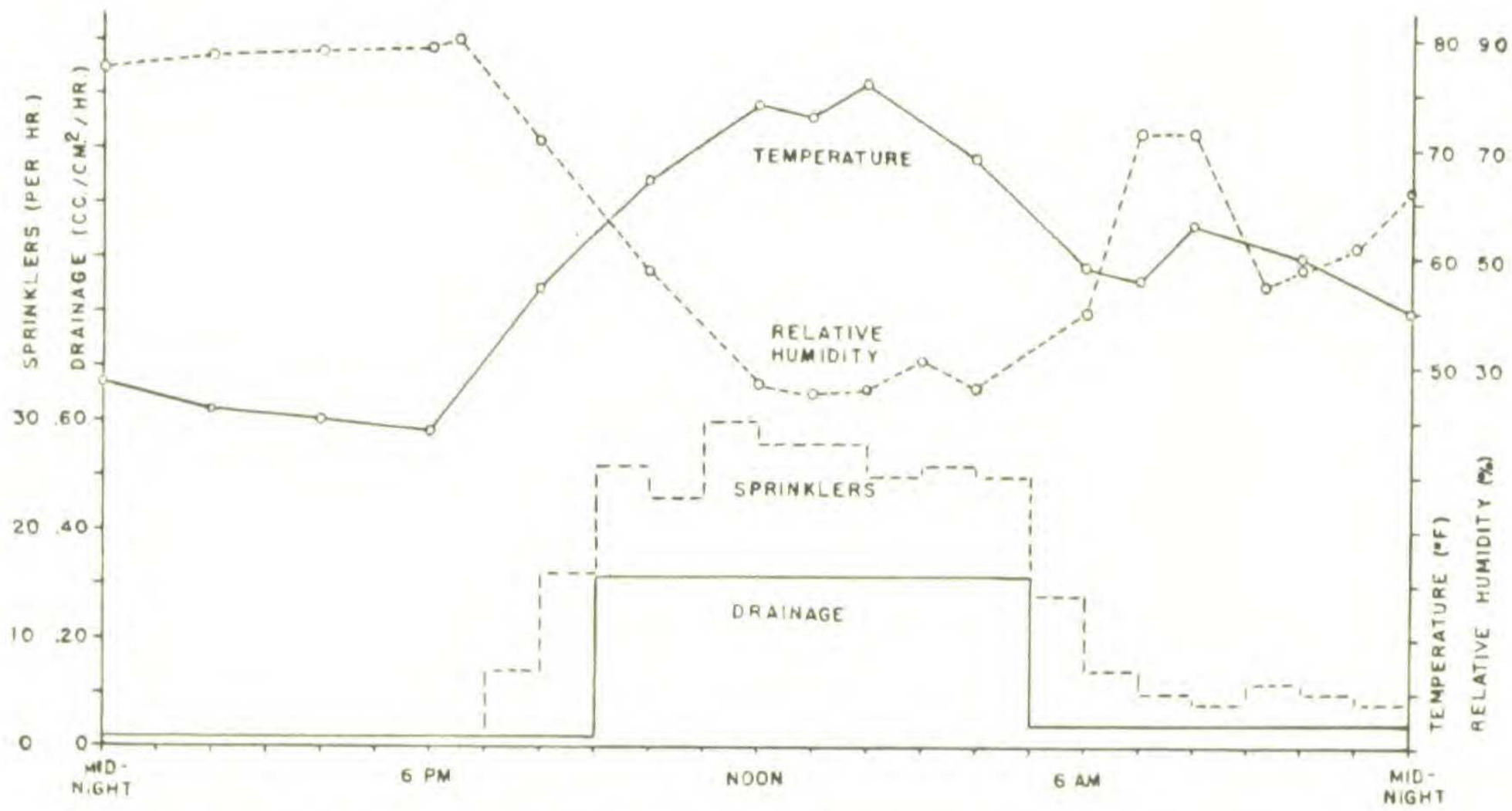

FIG. 3. Relation of sprinkler rate and drainage rate to relative humidity and temperature on August 28, 1944.

rate decreased. However, the humidity did not get as high as the preceding night, and the sprinkler rate leveled off at 4 to 6 times per hour. The unusual drop in humidity was reflected in the 9 P.M. to 10 P.M. sprinkler rate. Drainage for the overnight period was higher than for the previous night, as a result of the higher sprinkler rate.

ADAPTATION TO OTHER USES

The combination of regulator and locking relay with A.C. circuits seems to open up a new field for the use of porous bulbs, cones, or soil points to regulate watering mechanisms. As in the present case, the regulator may be activated by the drying effects of the atmosphere; or, in soil or sand, by the tension of the water film. The latter arrangement would enable one to construct automatic irrigating devices which would respond to the water tension in the soil, rather than merely the drying effects of the atmosphere.

Possibly controls of this type can be of value in certain industrial processes.

LITERATURE CITED

1. DORAN, WILLIAM L. The propagation of some trees and shrubs by cuttings. Mass. Agric. Exp. Sta. Bull. 342. 56 pp. 1941.
2. MITCHELL, H. L., C. S. SCHOPMEYER, and K. W. DORMAN. Pedigreed pine for naval stores production. Science n. s. 96: 559–560. 1942.
3. RAINES, M. A. Some uses of a spray chamber in experimentation with plants. Am. Jour. Bot. 27: Suppl. 18 (abstract). 1940.
4. SCHREINER, ERNST J. The possibilities of the clone in forestry. Jour. Forestry 37: 61–62. 1939.
5. STOUTEMYER, V. T. and F. L. O'ROURKE. Spray humidification and the rooting of greenwood cuttings. Am. Nurseryman 77(1): 5–6, 24–25. 1943.

HARVARD FOREST,
PETERSHAM, MASS.